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## Review of Invasive Riparian Trees that Impact USACE Ecosystem Restoration Projects

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**PURPOSE:** The U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL) developed this technical note to describe invasive woody trees and shrubs that negatively affect USACE riparian management and restoration activities. The USACE Ecosystem Management and Restoration Research Program (EMRRP) is supporting a nationwide effort to address the impacts of invasive woody plant species on ecosystem restoration, and more specifically, to determine mechanisms to address the most prevalent invasive species (by region) that impact restoration activities. This large research program has four objectives: (1) identify the group of invasive woody riparian plants that are most problematic to USACE ecosystem restoration efforts; (2) develop resource guidelines that suggest time and location thresholds in which funds should be spent to control invasive woody plants; (3) determine the most efficient and ecologically-effective spatial configuration for woody invasive riparian plant removal on Corps-managed lands; and (4) investigate how faunal communities respond to various spatial control methods for woody invasive plant removal in densely vegetated riparian habitats.

The USACE ecosystem restoration mission has provided numerous opportunities to rehabilitate degraded riparian systems. However, the spread of highly invasive non-native trees can significantly impact restoration efforts by increasing costs of removal and control, reducing overall extent of restoration efforts, and diminishing or compromising restoration goals aimed at rehabilitating native ecological communities. The purpose of this technical note is to: (1) provide an overview of invasive woody species that are invading riparian areas nation-wide; (2) identify the five most common invasive tree species; (3) review current USACE restoration projects and approaches to management of invasive species; and (4) provide recommendations for future management and restoration of riparian habitats.

**BACKGROUND:** Non-native species introduced intentionally, or otherwise, have affected native flora and fauna communities throughout North America. Whether these species are plants, animals, or pathogens (e.g., fungi, bacteria), costs from damages and losses, and costs of efforts for eradication, control, and monitoring have exceeded hundreds of billions of dollars over the past several decades (Pimentel et al. 2000, Pimentel et al. 2005). Currently, due to interactions with non-native species, approximately 400 species of threatened and endangered native plant populations are imperiled (Pimentel et al. 2000, Hayes and Holzmueller 2012). However, the presence of non-native species may have some positive impacts on local ecosystems. For example, non-native plants can provide cover and/or food for some vertebrate communities (Schlaepfer et

al. 2010, Hayes and Holzmüller 2012). In altered landscapes, particularly in the American Southwest, highly modified hydrologic regimes have resulted in riparian habitats that are no longer suitable for native cottonwood/willow plant communities (Stromberg et al. 2009). In such conditions, non-native species such as saltcedar (*Tamarix ramosissima*) provide habitat structure that otherwise would not be available. Originally, saltcedar was thought to provide low quality nesting habitat for the endangered Willow Flycatcher (*Empidonax traillii extimus*) (Sogge et al. 2003). However, upon further investigation, saltcedar not only provides nesting habitat for this flycatcher, but this bird has shown non-significant differences in nesting success in native and non-native habitats (Sogge et al. 2003, Owen et al. 2005). Saltcedar-dominated areas are now considered important breeding habitat for the survival and recovery of Southwestern Willow Flycatcher populations (Owen et al. 2005, Sogge et al. 2008, Stromberg et al. 2009).

Numerous other non-native riparian trees have invaded riparian areas throughout the United States. Identifying negative and positive impacts of such invasive species has important ramifications for the goals and objectives of riparian restoration efforts. For many of these species, eradication is either impossible, undesirable, or cost prohibitive. Species that form dense monocultures, such as saltcedar or Russian olive (*Elaeagnus angustifolia*), are often the primary woody species capable of growing in altered conditions. Complete eradication of these species can result in the removal of significant structural components of the ecosystem that provide habitats for many species. Without such structure, other native plant or animal populations may be negatively impacted (Stromberg et al. 2009, Schlaepfer et al. 2012, Wagner et al. *In review*). In addition, several species propagate prolifically from cuttings, stumps, stems, roots, and/or rhizomes, so partial removal of plant material may facilitate the spread of invasive species, compromising both removal efforts and restoration goals. In these cases, near-complete eradication may be necessary before restoration can proceed.

To initiate restoration projects, managers will need to balance overall goals of restoration efforts with anticipated costs and consequences. For some invasive riparian trees, it may be possible to reduce costs by focusing on partial removal while restoring native plant communities in discreet patches in a landscape. Under some scenarios, such a mosaic of native and non-native plant communities may provide sufficient habitat to support diverse plant and animal communities to meet restoration and conservation goals (Stromberg 1998a,b, Maskell et al. 2006, Fischer et al. 2012). Rapid propagation by residual stumps, cuttings, seeds, and rhizomes of certain non-native/invasive trees may incur significant costs for eradication before restoration of native plants can proceed with a reasonable probability of success. Such conditions require that managers become aware of the extent and distribution of non-native invasive species on project lands. From this information, managers can begin identifying cost-effective sites to focus riparian restoration efforts. To assist in this process, this technical note introduces five of the most common invasive riparian trees, provides brief information on their life history and introduction into the United States, and general approaches used for control and management. Two additional invasive species, the broad-leaved paperbark (*Melaleuca quinquenervia*) and Japanese knotweed (*Fallopia japonica*), are mentioned because of their potential to compromise current restoration efforts in the Everglades and Eastern United States, respectively. Finally, when confronted with non-native/invasive riparian trees, project managers are provided recommendations to guide decisions concerning location and method to proceed with riparian restoration.

## INVASIVE RIPARIAN TREES AND USACE RESTORATION PROJECTS

In May 2014, an email was sent to various USACE Corps Districts and offices nationwide requesting information about invasive species impacting restoration efforts. Results from this effort are summarized in Table 1. Japanese Knotweed continues to be a problem in the eastern United States, and it is becoming an issue in Washington State for the Seattle District. For central states, including Kentucky, Indiana, Ohio, and mid-Atlantic states including Pennsylvania, Maryland, Virginia, and West Virginia, various species of bush honeysuckle (*Lonicera* spp.) and an invasive variety of pear (*Pyrus calleryana*) are reoccurring problems. The non-native pear may become a greater problem in the future. As expected, several western districts have problems with Russian olive and saltcedar, but the Forth District, TX, noted seven species causing difficulties (Table 1). Current impacts with invasive trees like the Brazilian peppertree and Chinese pistache are not as severe as with Russian olive and saltcedar, but these trees could portend serious problems for future restoration efforts.

Table 1. Summary of invasive species impacting USACE restoration efforts as determined through email correspondence, May 2014.

USACE Divisions and Districts		Invasive Species of Concern
Divisions	Districts	
Great lakes and Ohio Rivers Division	Pittsburgh	Honeysuckle ( <i>Lonicera</i> spp.)
	Cincinnati	
	Louisville	
Mississippi Valley Division	St. Louis	Honeysuckle ( <i>Lonicera</i> spp.) Invasive Pear ( <i>Pyrus calleryana</i> )
North Atlantic Division	New York	Japanese Knotweed ( <i>Fallopia japonica</i> )
Northwestern Division	Seattle	Japanese Knotweed ( <i>Fallopia japonica</i> )
	Walla Walla	Russian olive ( <i>Elaeagnus angustifolia</i> )
South Pacific Division	Los Angeles	Salt Cedar ( <i>Tamarix</i> spp.)
Southwestern Division	Fort Worth	Saltcedar ( <i>Tamarix</i> spp.)
		Brazilian peppertree ( <i>Schinus terebinthifolius</i> )
		Chinese tallow tree ( <i>Triadica sebiferum</i> )
		Chinese pistache ( <i>Pistache chinensis</i> )
		Giant Cane ( <i>Arundo donax</i> )
		Privet ( <i>Ligustrum</i> spp.)
		Poison hemlock ( <i>Conium maculatum</i> )

## ECOLOGY AND CONTROL OF COMMON INVASIVE RIPARIAN TREES

### Russian Olive (*Elaeagnus angustifolia*).



Figure 1. Russian olive (*Elaeagnus angustifolia*) (Photo credit: Paul Wray, Iowa State University).

Russian olive (Figure 1) is native to central Asia and was planted in North America as early as the late 19th century. Original plantings may have been sporadic and largely for ornamental purposes, but by the early 20<sup>th</sup> century, this tree became widespread because of its purported value for wildlife, erosion control, and windbreaks. Shortly afterwards, the tree became naturalized and is now located throughout much of North America, particularly in the northwest. This species has a comparatively long germination period and can propagate by seeds or by vegetative growth. Rapid seed dispersal, usually by mammals and birds, plus an ability to expand in optimal to sub-optimal conditions has allowed this species to out-compete most other native riparian tree species, especially in the western United States (Katz and Shafroth 2003). Within many areas in the western United States, Russian olive can form thick monocultures that shade out virtually all other trees and understory vegetation. This species is found in 35 states within the conterminous United States (<http://plants.usda.gov/java/citePlants>) (USDA 2014), is the fourth most common tree found in western riparian habitats (Freidman et al. 2005), but is less common in the eastern portions of the country and absent or very rare in the southeast. Russian olive control can be labor intensive, involving mechanical and chemical control techniques. Katz (2015) provides a broad overview of Russian olive biology, invasion, and ecological impacts in North America.



## Saltcedar (*Tamarix ramosissima*).



Figure 2. Saltcedar (*Tamarix ramosissima*) (Photo credit: Leslie J. Mehrhoff, University of Connecticut).

Saltcedar (Figure 2), is a species adapted to dry, harsh conditions in Europe and Asia. This species was present in the United States as early as 1818 (Carpenter 1999, Stromberg et al. 2007). During the pre- and post-Depression era, wide-spread tree-planting efforts used this species to create windbreaks and to control soil erosion from agricultural fields. Since then, the species has become naturalized throughout the western United States, particularly in the southwest where it flourishes in hydrologically altered riparian systems (Stromberg et al. 2009). Saltcedar is a deciduous shrub with feathery leaves and conspicuous racemes of flowers. The species is known to have a large deep tap root system that allows access to lower water tables and is often associated with areas of high salinity typical in xeric or desert riparian habitats (Carpenter 1999). In the southwestern United States, demand for water in support of agriculture and urban uses has lowered existing water tables, favoring establishment of saltcedar rather than native cottonwoods (*Populus* spp.) and willows (*Salix* spp.). Once established, saltcedar can create dense thickets that may prevent the establishment of native trees. Although a few early studies indicated that the large tap root system of saltcedar might result in greater uptake of water than native trees, data from later studies indicated that saltcedar uses water at rates comparable to native trees (Stromberg et al. 2009). Moreover, removal of saltcedar would not necessarily result in a higher water table or more available water, since any increase in water would be subject to greater evaporation rates.

Like Russian olive, saltcedar creates woody structure that can be used by vertebrate species that would not otherwise be present (i.e., Southwest Willow Flycatcher (Sogge et al. 2003)). However, although saltcedar areas may provide suitable breeding areas for many birds, the value of such areas as stopover habitat during migration may be limited (Fischer et al. *In press*). Arguments that suggest saltcedar can outcompete native species have also been questioned. Saltcedar saplings can often be out-competed by native saplings (Sher and Marshall 2003), and there is some dispute about whether saltcedar actually displaces native species or simply colonizes areas no longer suitable for native vegetation (Stromberg et al. 2009). Saltcedar usually colonizes bare soil in areas

where land has been prepared for agriculture or other human uses (e.g., below dams). Such colonized areas often manifest altered fire and flood regimes, increased salinity, and increased herbivory that have simply favored saltcedar rather than native trees. Future efforts to remove saltcedar for restoration of native vegetative communities will need to be balanced while considering the lowered prospects for success in highly altered systems and the realization that by removing saltcedar one removes an increasingly important part of the woody structure in southwest riparian habitats (Stromberg et al. 2009).

### **Tree-of-Heaven (*Ailanthus altissima*).**



Figure 3. Tree-of-Heaven (*Ailanthus altissima*) (Photo credit: Chuck Barger, University of Georgia).

The Tree-of-Heaven (*Ailanthus altissima*) is a tree native to northeast and central China. Introduced to the United States for ornamental purposes in the late eighteenth century, the species was used to line busy streets in urban and downtown areas. The tree is now often found along roadways and growing in vacant urban lots; this is one of few trees that grows readily through cracks in urban pavement. This tree also can invade larger forest systems through roads, forest removals, and other disturbances. Chinese immigrants introduced the species to California during the gold rush era (Hoshovsky 1986). It is often associated with disturbed areas that are historically associated with mining. The tree has one of the fastest growth rates of any North American tree and grows rapidly in disturbed sites. It grows vegetatively from stumps, sprouts, and seeds. After World War II, the tree rapidly became naturalized throughout much of the United States, especially along the eastern seaboard and the southeast. The species is a medium sized, deciduous tree that is known for conspicuous flowers and abundant seeds; it also produces pungent odors by all parts of the tree. The odor is from a chemical, ailanthone, which inhibits the growth of vegetative competitors. This allelopathic trait probably explains the ability of this tree to displace native



species (Hoshovsky 1986). Although it usually invades disturbed areas, it can invade forested areas by exploiting tree-fall canopy gaps where it shades and out-competes native trees (Knapp and Canham 2000). Once established, it can be very difficult to eradicate. Typically, a combination of mechanical removal and chemical herbicides are needed (Meloche and Murphy 2006). The best approach is to prevent establishment of the tree by removing seedlings before a root system can become established (Hoshovsky 1986). However, all methods of control require significant time and labor, and for older established stands, large equipment may be needed (Meloche and Murphy 2006).

### **Chinese Tallow Tree (*Triadica sebiferum*).**



Figure 4. Chinese tallow tree (*Triadica sebiferum*) (Photo credit: Ted Boder, Southern Weed Science Society).

The Chinese tallow tree is native to Japan and China and thrives in subtropical and tropical zones. This tree was introduced to South Carolina in the late eighteenth century for ornamental purposes (Bolger 2000). Since its introduction, it has spread to every coastal state in the southeast, inland to Arkansas and Texas, and has recently invaded riparian areas in California (Bolger 2000). This tree often invades native grass prairies and riparian forest habitats, especially in coastal zones. The tree is fast-growing, shade tolerant, and typically found in mesic to hydric wetlands; it can invade both disturbed and non-disturbed sites. Like the Tree-of-Heaven, it has been able to invade forested areas by exploiting tree-fall canopy gaps or other disturbances from storms and hurricanes (Smith et al. 1997). Like other invasive trees, it reproduces by cuttings and copious seed production. The

seeds are often dispersed by birds (Renne et al. 2000), but the seeds can also float long distances (Bolger 2000). This species also has allelopathic traits that can alter soils, creating conditions unsuitable for many native plant species. In addition, arthropod communities in Chinese tallow tree stands tend to include more non-native species than native species, indicating that the ecological impacts of this tree extend beyond just the plant community (Miller and Cameron 1983). Eradication of Chinese tallow tree usually involves mechanical removal and herbicide applications. Because of the ability of this tree to sprout from stumps and cuttings, prescribed burning is only successful in dry habitats; burning is usually unsuccessful in wetlands. Saplings and small trees can be removed by hand or power saws; removing downed fruit may also limit growth of new saplings (Bolger 2000). An herbicide must be applied to remaining stumps. As with other invasive trees, the best approach is to remove saplings before they become established.

### **Autumn Olive (*Elaeagnus umbellata*).**



Figure 5. Autumn olive (*Elaeagnus umbellata*) (Photo credit: James R. Allison, Georgia Department of Natural Resources).

Autumn olive is native to China, Japan, and Korea, and was introduced into the United States for ornamental purposes and cultivation (Sather and Eckardt 1987). The small tree or shrub is sometimes planted for wildlife cover and fruit production in the central and eastern portions of the country. It is capable of invading disturbed areas where it can form impenetrable thickets. Although it does not seem tolerant of wet or very dry sites, it can exploit poor soils because of its superior ability to fix nitrogen (Sather and Eckardt 1987). This tree exhibits significant resprouting capabilities after cutting and burning, and like other invasive species, produces large annual seed crops. Problem areas typically include sites where this tree was planted in small stands or rows. Stands next to nature preserves should be monitored to ensure that new stands do not establish. Areas subject to repeated prescribed burnings are also likely troublesome because of this tree's ability to rapidly regrow and spread after disturbance (Sather and Eckardt 1987). Mechanical



removal alone will not suffice, and a combined approach using mechanical and chemical treatments are usually required to remove existing stands.

### Other notable species.



Figure 6. Broad-leaved paperbark (*Melaleuca quinquenervia*) (Photo credit: Barry Rice, sarracenia.com).

Broad-leaved paperbark (Figure 6) is a wetland tree species native to New Caledonia, Papua New Guinea, and the eastern coast of Australia. This species was introduced for ornamental purposes in the early twentieth century and has become naturalized in southern Florida where it can dominate forested, wetland communities and threaten efforts to restore the Everglades (Laroche and Ferriter 1992). It is also found in other states including South Carolina, North Carolina, Massachusetts, Oklahoma, and Texas. This tree was introduced in Florida with the intent of creating forested habitat in the Everglades that would reclaim wetlands for development (Hofstetter 1988). This tree can invade disturbed areas easily, and each tree may produce thousands of seeds. Moreover, seeds can remain viable for many years, and trees often release seeds in periods of stress, including periods when exposed to herbicides or mechanical disturbances. Such characteristics make this species very difficult to control (Laroche and Ferriter 1992). In general, expansion of broad-leaved paperbark is centralized around the original introduction and surrounding areas that have been disturbed. Once established, this tree creates a dense canopy that can potentially shade-out native plant communities. Without control, this tree has the potential to damage existing wetland habitats in the Everglades, which compromises current restoration efforts.



Figure 7. Japanese Knotweed (*Fallopia japonica*) (Photo credit: Barry Rice, sarracenia.com).

Japanese Knotweed is a herbaceous perennial, but is noted because it is a serious invasive species that dominates riparian areas, especially in the eastern United States. However, this species has recently become a problem in western states as well. This plant was likely introduced in the 19<sup>th</sup> century as an ornamental plant. It tolerates floods, droughts, and areas of poor soils or soils with high salinity. Along the Allegheny and Ohio rivers, it is reported to occupy hundreds of acres of wetland and riparian habitat (Seiger 1992). This species can rapidly colonize shorelines and sandbars, creating dense, impenetrable thickets. However, this species does not appear to be a threat to undisturbed areas. Japanese knotweed creates dense thickets that reduce overall diversity of the plant community and probably have a negative impact on native animal populations as well (Seiger 1992). This plant can propagate by seeds and rhizomes; expansion appears largely due to rhizomes being transported downstream to suitable habitats (Seiger 1992). As with other invasive riparian plants, the best control is to prevent establishment by monitoring and manually removing seedlings and young plants (Seiger 1992). Cutting or digging up plants may be effective with a small population; however, care should be taken not to disperse rhizomes during the process. This invasive plant is shade intolerant and does not become established in areas with high grazing pressure (Seiger 1992). Once established, this species is very difficult to eradicate. Mechanical removal and herbicide applications are the preferred approach to control established stands. Re-application of such approaches is needed to ensure that the plant does not recolonize the area after eradication.

## DISCUSSION AND RECOMMENDATIONS

Continuing efforts to restore native riparian communities are needed to meet conservation and ecological restoration goals. As a principle government agency involved in the management of coastal areas, reservoir projects, and riverine infrastructure and flood control efforts, USACE has a vested interest in the health and viability of riparian habitats. Moreover, numerous state, federal, and organizational regulations mandate USACE project managers protect and conserve natural

resources, especially threatened and endangered species, while also controlling invasive species. Successful restoration of riparian areas allows USACE managers to meet conservation goals by creating or improving habitat for many sensitive and rare native plants and animals. One obstacle to meeting restoration goals is the vast number and extent of non-native riparian trees that have the potential to decrease habitat quality for native plant and animal communities, increase restoration costs by having to control or eradicate non-native species, and potentially compromise the success of restoration by limiting the size and scope of the restoration effort. Here we provide an introduction to five of the top invasive riparian trees that managers may have to contend with during restoration of degraded riparian areas nation-wide.

Restoration efforts are unique, and different regions will likely have different suites of potential non-native species to manage or control. Several invasive species noted here, including Russian olive and saltcedar, form extensive monocultures that may be difficult and cost-prohibitive to eradicate. However, both species may invade degraded areas where native species either cannot become established or are unable to compete. In such cases, these species may provide a source of woody structure for many vertebrates that otherwise would not be present. In these cases, managers may be able to develop cost-effective strategies that remove non-natives in targeted patches while leaving other areas intact. The impacts of such an approach are not completely understood, but studies on mixed native/non-native plant communities and faunal communities (Van Riper et al. 2008, Fischer et al. 2012, Wagner et al. *In review*) and ongoing research on specific removal patterns of Russian olive thickets on seasonal bird communities (Fischer, unpubl. data) may provide some insight for future management. Additional research will be needed when dealing with other non-native trees in other regions. The goal of such an approach is to maintain sufficient habitat for existing plant and animal communities while providing areas to restore native communities for long-term sustainability of native populations in a cost-effective manner. Such an approach may result in a mosaic landscape of native dominated and non-native dominated plant communities. Some research suggests that mosaic landscapes are capable of maintaining biodiversity and other ecological functions (Stromberg 1998, Maskell et al. 2006) and may represent a cost-effective approach to large-scale removal of native-dominated habitats. Further research is needed to clarify the value and cost-effectiveness of maintaining patches of both native and non-native plant communities. However, a driving force behind implementation of a mosaic approach may simply be the extreme cost and low probability of actual eradication of many non-native plant species.

Other species noted here have significant capabilities to propagate through remaining stumps, cuttings, seeds, or rhizomes, and mechanical control techniques may increase risk of spreading some of these species (i.e., tree-of-heaven, Chinese tallow tree, broad-leaved paperbark, and Japanese knotweed). In these cases, managers should identify the extent and distribution of these species on their lands and identify areas for restoration where such invasives are absent or in low abundance to facilitate eradication. In some cases when restoration of riparian habitat is a priority, there may be few options other than an expensive removal project in areas targeted for restoration.

There are numerous reports and guidelines for how to manage non-native species. Lodge et al. (2006) provided a review of the issues and provided numerous recommendations for U.S. government policy and management. Most of these focus on prevention of future introductions and limit the extent of current invasions. For USACE project managers, such recommendations



may be of little use if existing riparian habitats are already dominated by non-native species. Several broad guidelines are provided for USACE riparian restoration projects already contending with the invasive trees discussed in this note:

1. Determine extent and distribution of an invasive species on project lands. If few or no invasive species are found, implement seasonal (e.g., growing season) monitoring to identify any potential colonization of invasive species within the project jurisdiction. Prevention of invasive establishment is the best, most cost-effective means to limit long-term control and eradication costs. Once saplings are identified, use manual removal or careful herbicide applications to eradicate invasives before they become established.
2. If an invasive species is found established on project lands, determine if the species needs to be eradicated, or if creation of a mosaic of native and non-native patches may meet restoration and/or conservation goals. Trees such as saltcedar and Russian olive are difficult and expensive to eradicate, but restoration of native trees in some areas may provide benefits to some vertebrate species (Wagner et al. *In review*). Leaving patches of invasive trees can reduce overall costs of control and provide some benefits to other vertebrates.
3. Beware of species that propagate through extensive roots, stumps, cuttings, seeds, and rhizomes. Application of manual or mechanical removal approaches (including prescribed burns) may actually promote spread of invasives on project and adjacent lands. Consult with a specialist on the best, most cost-effective approach to remove invasive trees in target areas.
4. For species that produce large quantities of seeds, consider if removal of downed seeds may reduce reestablishment of the invasive tree.

**SUMMARY:** Invasive riparian tree species can pose a serious obstacle to USACE riparian restoration efforts by increasing costs for control or eradication and potentially compromising the success of restoration by limiting the size and scope of the project. In this note, we introduce five of the most common invasive trees in the United States that may hinder riparian restoration efforts on USACE project lands. These species include Russian olive, saltcedar, tree-of-heaven, Chinese tallow tree, and autumn olive. Two additional species, broad-leaved paperbark and Japanese knotweed are also included because of their potential to compromise restoration in the Everglades and eastern riparian areas, respectively. In some situations, particularly areas subject to significant hydrological alterations, these species may invade areas that are no longer suitable to native plant communities. In these cases, these invasive species can provide habitat for other plants and animals that would otherwise be absent. Maintaining a mosaic of patches that include both native and non-native/invasive species may provide a cost effective approach that permits restoration of native trees and reduces time and expense of non-native eradication and control. Several of the species described herein have the capability to propagate through roots, stumps, cuttings, seeds, and rhizomes, and manual or mechanical removal may actually promote the spread of the species. Control or eradication of such species may best be accomplished through a combination of approaches including manual removal, herbicide application, and mechanical disturbance/removal. A list of recommendations is provided that may assist USACE project managers on how to approach riparian restoration when contending with non-native/invasive trees on project lands.

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